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ScienceDirect
Renewable and Sustainable Energy Reviews 13 (2009) 253–270
RENEWABLE & SUSTAINABLE ENERGY REVIEWS
www.elsevier.com/locate/rser

Energy and environmental issues relating to greenhouse gas emissions for sustainable development in Turkey

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Received 19 June 2007; accepted 20 July 2007

Abstract

Turkey's demand for energy and electricity is increasing rapidly. Since 1990, energy consumption has increased at an annual average rate of 4.3%. As would be expected, the rapid expansion of energy production and consumption has brought with it a wide range of environmental issues at the local, regional and global levels. With respect to global environmental issues, Turkey's carbon dioxide (CO_2) emissions have grown along with its energy consumption. Emissions in 2004 reached 193 million tons. States have played a leading role in protecting the environment by reducing emissions of greenhouse gases (GHGs). State emissions are significant on a global scale. CO_2 and carbon monoxide (CO) are the main GHGs associated with global warming. At the present time, coal is responsible for 30–40% of the world CO_2 emissions from fossil fuels. Sulfur dioxide (SO_2) and NO_x contribute to acid rain. Carbon assessments can play an important role in a strategy to control CO_2 emissions while raising revenue.

Keywords: Greenhouse gas emissions; Global warming; Environmental policy; Turkey

Contents

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1364-0321/$ - see front matter
doi:10.1016/j.rser.2007.07.009

1. Introduction

Energy is essential to economic and social development and improved quality of life in Turkey as in other countries. Much of the world's energy, however, is currently produced and consumed in ways that could not be sustained if technology were to remain constant and if overall quantities were to increase substantially. The need to control atmospheric emissions of greenhouse and other gases and substances will increasingly need to be based on efficiency in energy production, transmission, distribution and consumption in the country. On the other hand, electricity supply infrastructures in Turkey as in many developing countries are being rapidly expanded as policy-makers and investors around the world increasingly recognize electricity's pivotal role in improving living standards and sustaining economic growth. On the contrary, in the coming decades, global environmental issues could significantly affect patterns of energy use around the world as in Turkey. Any future efforts to limit carbon emissions are likely to alter the composition of total energy-related carbon emissions by energy source in the country [1–4].

Turkey has made significant progress with regard to environmental protection but more still needs to be done. The UNFCCC entered into force in May 2004 [5]. The country is in the process of developing its Climate Change Strategy and first national communication to the UNFCCC. The government should strive to monitor the effectiveness of the chosen policies and measures, both in terms of costs and emissions reductions. It should also consider defining an emissions target based on the momentum of the UNFCCC ratification. Coordination among the various government bodies will be key to the success of the strategy. Turkey has made significant progress in reducing local air pollution, particularly in large cities, but work remains to be done to ensure existing standards are met and to prepare for further reductions in air pollution. In this respect, it will be important to ensure that all market operators, including those owned by the State, comply with the existing air quality and emissions legislation.

The general approach of Turkey's energy policy has been highly supply-oriented, with emphasis placed on ensuring additional energy supply to meet the growing demand, while energy efficiency has been a lower priority. Consistently high-energy intensity and its imminent increase, partly attributable to the improving living standards, are matters of concern. To realize an energy savings potential of 25–30%, an energy-efficiency strategy was developed in 2004 and the government is preparing an energy-efficiency law. These positive developments lift the status of energy efficiency and conservation as part of the government's energy policy but stronger policies beyond those in the law are still needed. The evident lack of a comprehensive and co-ordinated energy-efficiency policy for the transport sector is of particular concern [6].

The government wishes to maintain hard coal production to enhance fuel diversity, and consequently security of supply, but the policy is also closely related to social, regional and employment policies. Given its poor competitiveness, Turkish hard coal receives high and increasing subsidies per ton. Turkey has large lignite resources, which make a far bigger contribution to its security of supply and are much more competitively priced than its hard coal resources ever could be. Nonetheless, there is a need for vigorous pursuit of productivity so that coal can compete as a fuel on equal grounds, even in the face of costs associated with tightening environmental requirements [5–7].

Turkey's use of hydropower, geothermal and solar thermal energy has increased since 1990. However, the total share of renewable energy sources in total primary energy supply (TPES) has declined, owing to the declining use of non-commercial biomass and the growing role of natural gas in the system. The fixed feed-in tariffs and purchase obligation for distribution companies under the proposed new Renewable Energy Law can encourage investments. The maximum level, 6 eurocents per kW h, is moderate as compared to the levels given, for example, to wind power in some developed countries such Germany, UK and Greece. While the scheme may not become excessively expensive for consumers, which is a common risk in feed-in tariffs, careful monitoring and adjustment of the cost of the scheme will be necessary until it is fully replaced by the purchase obligation in 2011. Given the diverse availability of resources among different distribution areas, it needs to be ensured that distribution companies can buy renewable electricity from certified producers located in other distribution regions to be able to fulfill their obligation at minimum cost. Despite a large potential for use of heat from renewable energy sources such as biomass, geothermal, and solar thermal, there are no specific policies in place for heat production from these renewables [7].

Turkey has recently announced that it will reopen its nuclear program in order to respond to the growing electricity demand while avoiding increasing dependence on energy imports. The competitiveness of nuclear power in a liberalized electricity market in Turkey needs to be

clarified. Investment decisions should be made on the basis of efficient and transparent price signals regardless of whether power plants are being built by private or public companies. Furthermore, waste disposal options need to be defined from the outset of launching a nuclear power project. Despite a high reserve margin of 40%, Turkey will need more capacity in the midterm because electricity demand will continue to grow rapidly. The recently launched rehabilitation program for the thermal power plants to increase their efficiency is a prudent approach as it postpones the need to invest in new capacity. Nonetheless, new capacity will be needed in the next decade, which requires a good investment climate. Despite some reductions in distribution losses during the last couple of years, both technical and non-technical losses (totaling about 15–20% in 2005) are still a concern. One notable development is the progress in the project to interconnect with the European Union for the Co-ordination of Transmission of Electricity (UCTE) network, which is scheduled for 2007 [5–7].

Given that Turkey is facing significant energy and environment policy challenges, the government needs to explore all possible means to respond to these challenges, including formulating a coherent energy research and development policy. To implement such a policy, a coherent energy strategy with adequate financing as well as good co-operation among the different ministries is necessary. This could be done by building on the work done for the National Research and Technology Foresight Program (Vision 2023 Program) [8].

2. Overview of Turkey

2.1. Geography, population and economy

Turkey's geographical location makes it a natural bridge between the energy-rich Middle East and Central Asian regions. Energy is one of Turkey's most important development priorities. Rapid increases in domestic energy demand have forced Turkey to increase its dependence on foreign energy supplies and to face the prospect of a severe energy shortage in the 21st century. Energy is essential to economic and social development and improved quality of life in Turkey as in other countries. Energy is considered a prime agent in the generation of wealth and also a significant factor in economic development [9].

The Turkey is located between Europe and Asia. Its surface area is 781,000 km^2 of which approximately 97% is in Asia and 3% is in Europe. Turkey's coastlines total more than 8333 km. Turkey's geographical location makes it a natural land bridge connecting Europe to Asia. Therefore, it has an increasingly important role to play as an "energy corridor" between the major oil and natural gas producing countries in the Middle East and Caspian Sea and the Western energy markets [9].

In 2004, the population of Turkey was 71.3 million, 26% over the 1990 level. The average population growth rate was 1.8% per year between 1990 and 2004. Population growth is envisaged to gradually slow down to 1.6% in 2005, 1.4% in 2010 and 1.1% in 2020. With these growth rates, the population would reach almost 88 million by 2020. Turkey is experiencing high domestic migration rates towards cities [9].

The economy has undergone a significant shift from agriculture towards the service sector and to some extent industry, although some 30% (43% in 1993) of the active population was still employed in agriculture in 2003. The unemployment rate was 9% in mid-2004, three percentage points above the 2000 level. However, the employment rate is only 46% of the labor force, the lowest in OECD member countries and labor productivity is around 35% of the OECD average.

Turkey suffered from the most severe economic difficulties of its recent history in 2001 caused by a banking crisis resulting from a widening current account deficit and fragile foreign confidence. The gross domestic product (GDP) declined by 7.5% in 2001 but recovered by 6% in 2003 and 6.4% in 2004. The Turkish economy is currently among the fastest growing economies in the OECD. It is driven by strong productivity gains and by robust growing private consumption, investments and exports, and has not been hindered by cuts in government consumption and investment. In 2004, GDP per capita in Turkey, measured using current purchasing power parities, was US$6800, which is 26% of the OECD average. A major problem is the significant extent of unregistered activities that account for more than 50% of total employment and lead to a narrowing of the tax base [9,10].

3. Turkey's energy policy and energy sector

Turkey has dynamic economic development and rapid population growth. It also has macro-economic, and especially monetary, instability. The net effect of these factors is that Turkey's energy demand has grown rapidly almost every year and is expected to continue growing, but the investment necessary to cover the growing demand has not been forthcoming at the desired pace. Turkey's primary energy reserves (Table 1) are not enough to meet energy demand. Turkey is an energy-importing nation with more than 74% of total energy consumption (Tables 2 and 3) met by imported fuels such as oil, natural gas and hard coal [5–7].

In 2005, TPES in Turkey was 83.7 million tons of oil equivalent (Mtoe), up by 58% from the 1990 level and 129.63 Mtoe in 2005, growing in phase with GDP. Dependence on oil has declined from 51% in 1973 to 31% in 2005. Natural gas demand has grown almost sevenfold since 1990, gaining a 32% share in TPES. The share of coal in TPES is 27%, down from 32% in 1990 and the share of combustible renewables and wastes 7%, down from 14% in 1990. Given hydropower production's dependence on weather conditions, annual variations tend to be large; however, the longer-term trend has been

Table 1
Primary energy reserves in Turkey (2002)

Energy sources	Proven	Probable	Possible	Total
Hard coal (million ton)	428	456	245	1129
Lignite (million ton)				
Elbistan	3357			3357
Others	3982	626	110	4718
Total	7339	626	110	8075
Asphaltite	45	29	8	82
Bitumes	555	1 086		1641
Hydropower				
GW h/year	126,109			126,109
MW/year	35,539			35,539
Petroleum (million ton)	39			39
Natural gas (billion m^3)	10.2			10.2
Nuclear sources (ton)				
Uranium	9129			9129
Thorium	380,000			380,000
Geothermal (MW/year)				
Electricity	200		4300	4500
Thermal	2250		28,850	31,100
Solar energy				
Electricity				8.8
Heat				26.4

Source: Ref. [6].

Table 2
Total final energy production in Turkey (Mtoe)

Energy sources	2005	2010	2020	2030
Coal and lignite	20.69	26.15	32.36	35.13
Oil	1.66	1.13	0.49	0.17
Gas	0.16	0.17	0.14	0.10
Nuclear	–	–	7.30	14.60
Hydropower	4.16	5.34	10.00	10.00
Geothermal	0.70	0.98	1.71	3.64
Solar/wind/other	0.22	1.05	2.27	4.28
Total production	27.59	34.77	54.27	71.68

Source: Ref. [6].

Table 3
Total final energy consumption in Turkey (Mtoe)

Energy sources	2005	2010	2020	2030
Coal and lignite	35.46	39.70	107.57	198.34
Oil	34.60	51.17	71.89	102.38
Gas	19.40	49.58	74.51	126.25
Nuclear	–	–	7.30	14.60
Hydropower	4.16	5.34	10.00	10.00
Geothermal	1.89	0.97	1.71	3.64
Solar/wind/other	0.22	1.05	2.27	4.28
Total primary energy consumption	95.28	147.81	275.25	459.49

Source: Ref. [6].

increasing supply owing to new capacities. Production of geothermal energy has almost doubled since 1990 reaching 0.86 Mtoe. Solar and wind contributed 1.36 Mtoe in 2005 (see Tables 4 and 5).

As seen in Fig. 1, domestic energy production was 23.8 Mtoe in 2003 (28% of TPES) and comprised coal (10.8 Mtoe), renewables (10 Mtoe), oil (2.5 Mtoe) and gas (0.5 Mtoe). In 2005, domestic energy production was 27.6 Mtoe [5–10]. The government forecasts both oil and gas production to decline owing to depletion of resources but coal production (principally lignite) and renewable energy production to increase (see Figs. 1–4).

4. Energy and climate change

The greenhouse effect is a natural phenomenon linked to the absorption of solar energy by the Earth's atmosphere. Part of the long-wave infrared radiation emitted by the sun is not reflected back into space by the Earth's surface but is absorbed by greenhouse gases (GHGs) naturally occurring in the atmosphere. This radiation is transformed into heat, resulting in a stable average temperature of 15 °C in the Earth's atmosphere. However, through the sustained release and accumulation in the atmosphere of GHGs since the industrial revolution, human societies are affecting this natural balance, resulting in the disturbance of normal climatic cycles. Because of the long residence times of GHGs in the atmosphere, measured in centuries in the case of CO_2, and the inertia of the climate system, climate change would still constitute a risk, as a result of past emissions, even if human-induced emissions suddenly ceased [11–15].

There are skeptics to the existence of human-induced climate change but the broad scientific consensus on climate change is unequivocally represented by the Intergovernmental Panel on Climate Change (IPCC). The IPCC was formed in 1998 under the auspices of the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP). The IPCC reports on international research efforts carried out in the atmospheric, social and economic sciences, documented into assessment reports on the three themes of science, mitigation options and adaptation measures [16–19]. On the other hand, some 30 gases contribute to the anthropogenic greenhouse effect, but only six are regulated by the Kyoto Protocol. Many of the other gases are already regulated by other international protocols, for example the Montreal Protocol on substances that deplete the ozone (O_3) layer, or are not released in sufficient quantities to be regulated or, like water vapor, are not controllable by human intervention. The six GHGs specified in the Kyoto Protocol are set out in Table 6 [20].

4.1. Energy and environmental policies of Turkey

Turkey made great progress over the last 15 years in creating mechanisms to address its environmental problems:

Table 4
Renewable energy supply in Turkey

Renewable energy sources	1990	1995	2000	2002	2005
Primary energy supply					
Hydropower (ktoe)	1991	3057	2656	2897	4067
Geothermal, solar and wind (ktoe)	461	654	978	1142	1683
Biomass and waste (ktoe)	7208	7068	6457	5974	5325
Renewable energy production (ktoe)	9660	10,779	10,091	10,013	11,074
Share of total domestic production (%)	38	40	38	40	48
Share of TPES (%)	18	17	12	13	12
Generation					
Hydropower (GW h)	23,148	35,541	30,879	33,684	47,287
Geothermal, solar and wind (GW h)	80	86	109	153	490
Renewable energy generation (GW h)	23,228	35,627	30,988	33,837	47,777
Share of total generation (%)	40	41	25	26	29
Total final consumption					
Geothermal, solar and wind (ktoe)	392	580	910	1048	1385
Biomass and waste (ktoe)	7208	7068	6457	5974	5325
Renewable total consumption (ktoe)	7600	7648	7367	7022	6710
Share of total final consumption (%)	18	15	12	12	10

Source: Refs. [6,7].

Table 5
Renewable energy projections in Turkey

Renewable energy sources	2010	2015	2020	2025	2030
Hydropower (ktoe)	4903	7060	9419	11,214	14,214
Geothermal, solar and wind (ktoe)	2896	4242	6397	8426	10,526
Biomass and waste (ktoe)	4416	4001	3925	3365	5665
Renewable energy production (ktoe)	12,215	15,303	19,741	21,342	24,342
Share of total domestic production (%)	33	29	30	28	26
Share of TPES (%)	10	9	9	8	7
Hydropower (GW h)	57,009	82,095	109,524	129,876	150,876
Geothermal, solar and wind (GW h)	5274	7020	8766	9786	11,686
Renewable energy generation (GW h)	62,283	89,115	118,290	135,678	165,678
Share of total generation (%)	26	25	25	24	24
Geothermal, solar and wind (ktoe)	2145	3341	5346	7413	9513
Biomass and waste (ktoe)	4416	4001	3925	3246	3646
Renewable total consumption (ktoe)	6561	7342	9271	10,786	11,786
Share of total final consumption (%)	7	6	6	5	5

Source: Refs. [6,7].

the 1982 Constitution recognizes the right of citizens to live in a healthy and balanced environment; an Environment Act was passed in 1983; the Ministry of Environment was establish in 1991; public awareness and demand for a clean environment are growing; and active non-governmental environmental organizations are emerging. Despite these positive developments, environmental issues have not been adequately incorporated into economic and social decisions yet [2,21].

This inadequacy is recognized, and the development of a national environmental strategy is a priority in Turkey's Eight Five Year Development Plan for 2001–2005 [10], including those for environmental management. Thus, the National Environmental Action Plan (NEAP) that has been prepared over a 2-year period responds to the need for a strategy and can supplement the existing development plan. The options related to energy and environmental policies are [21]:

- support the utilization of clean and renewable energy sources as well as geothermal, hydropower, biomass and passive solar energy applications;
- decentralization in energy generation;
- optimizing sustainability of energy supply and reducing environmental costs;
- organization of energy crisis management units at national and regional levels;
- enforcement of regulations and other arrangements to regulate the energy efficiency of domestic appliances;
- implementation of heat Insulation Regulation;

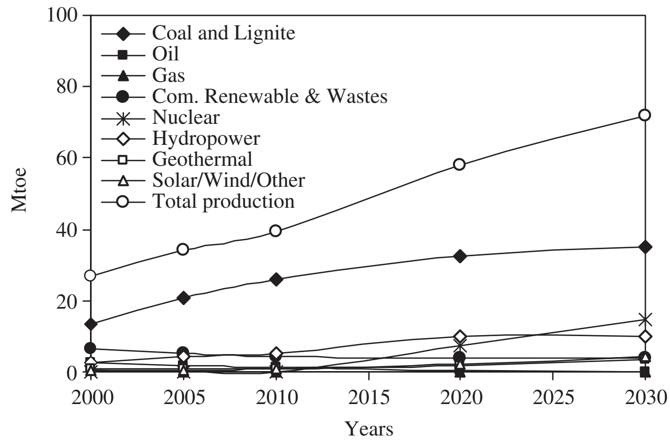

Fig. 1. Turkey's primary energy production during 2000–2030 [46].

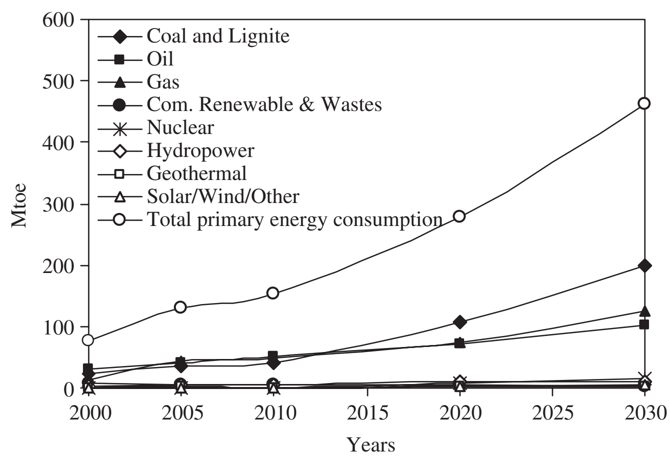

Fig. 2. Turkey's primary energy consumption forecast 2000–2030 [46].

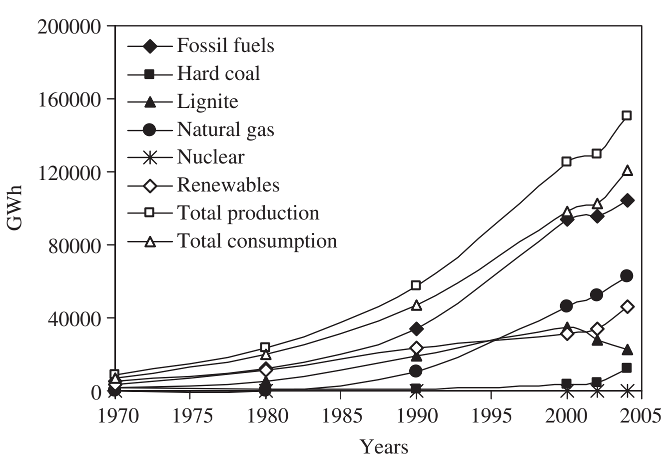

Fig. 3. Turkey's electricity production during 1970–2005 [46].

- organization of energy conservation training at adult education centers;
- people's participation to design and implement energy conservation programs;
- introduction of emission taxes in the pricing of fuels;
- support for the spread of energy-efficient techniques and technologies;
- encouraging the use of high efficiency–low emission stove and boiler systems;
- improvement of power transmission lines;
- promoting the diffusion and efficiency of central heating systems;
- wider use of process energy (e.g. co-generation);
- support for energy-efficient technology transfer in industry;
- improvement of techniques for energy consumption calculations in buildings;
- support the replacement of appliances with low energy efficiency;
- use of fluidized bed boiler systems in power plants and industries;
- development of techniques that increase energy efficiency;
- inventory of carbon emissions.

Major potential solutions to environmental problems are [2]:

- cleaner technologies,
- renewable energy technologies and
- efficient energy conversion technologies.

4.2. Global warming and greenhouse gas emissions

Energy is essential for economic growth, and although the link between growth and energy use has become weaker the world's demand for energy is increasing rapidly, leading to greater competition for finite natural resources. Energy that comes from fossil fuels produces GHGs, which if not mitigated, threaten the stability of the world's climate. We will need to tackle that challenge as our own natural resources decline, and we become more dependent on imported fuels. We need therefore, to establish a strategy which delivers both energy and climate security. It is not sustainable to achieve one without the other. The investment decisions taken over the next two decades will be critical in determining the world's energy and climate security and, therefore, its economic future.

The International Energy Agency's "business as usual" analysis takes into account policies already enacted or adopted by Governments up to mid-2006. It forecasts that between 2004 and 2030 [22]:

- global primary energy demand will rise by 53%, leading to a 55% increase in global carbon dioxide (CO_2) emissions related to energy;
- fossil fuels will remain the dominant source of energy worldwide, meeting 83% of the increase in energy demand;
- emissions from power generation will account for 44% of global energy-related emissions by 2030, as demand for electricity rises;

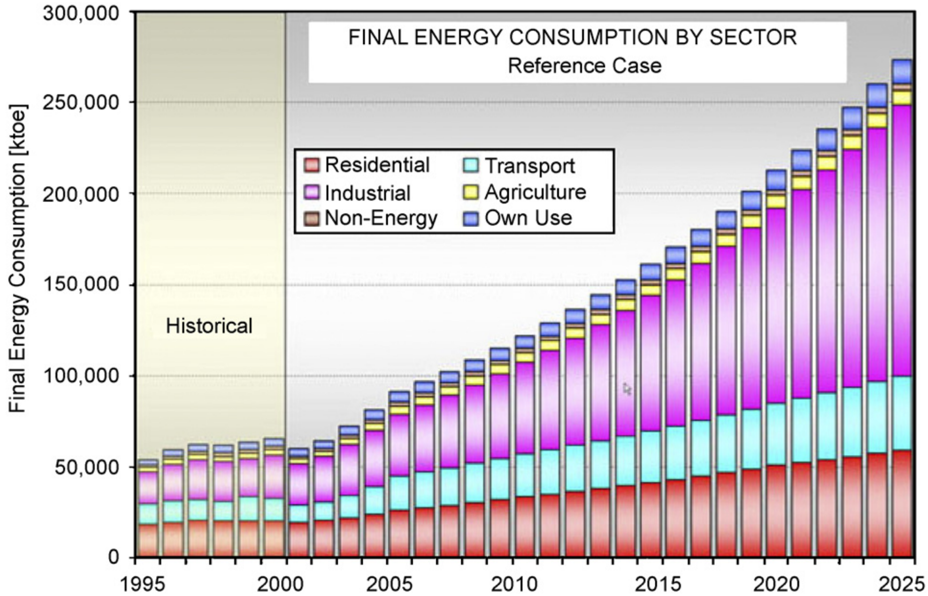

Fig. 4. Reference case final energy consumption by sector [23].

Table 6
Greenhouse gases covered by the Kyoto Protocol

Chemical species	Formula	Abundance (ppb) (1750)	Abundance (ppb) (1998)	100-year GWP*	Main sources
Carbon dioxide	CO_2	278,000	365,000	1.0	Combustion of hydrocarbons for energy; deforestation
Methane	CH_4	700	1745	21	Waste management; agriculture
Nitrous oxide	N_2O	270	341	296	Agricultural soils; biomass burning
Hydrofluorocarbons	HFCs	0	7	120–1200	Mostly refrigerant fluids
Perfluorocarbons	PFCs	20	40	6000–12,000	Industrial processes
Sulfur hexafluoride	SF6	0	4.2	22,200	Industrial processes

Note: *The GWP Index indicates the relative impact compared to CO_2.
Source: Ref. [20].

- coal will provide the largest incremental source of power generation, with the majority of this increase likely to be in China (55%);
- over 70% of the increase in global primary energy demand will come from developing countries; reflecting rapid economic and population growth; and
- some $20 trillion of investment will be needed throughout the energy supply chain.

The challenge facing the world is to meet rising energy demand, to support economic growth while moving towards a low carbon economy [22].

Global warming is another issue where energy questions will be the subject of considerable international political activity. It is an issue that raises key questions about politically sensitive topics, such as national sovereignty and international equity, but the Kyoto conference, attended by 160 countries in December 1997, and world summits, such as the Rio and Montreal meetings, showed that most governments feel the need to address the question. According to the Kyoto protocol, so-called Annex I countries (OECD Members plus economies in transition) must reduce their emissions of six GHGs by at least 5% compared with 1990 levels over 2008–2012 [11–13].

Global warming and nuclear risks are considered on an international level, but risks linked to possible resource scarcity or soil degradation and land use are not the subject of international negotiations. On the other hand, CO_2 and

CO are the main GHGs associated with global warming. At the present time, coal is responsible for 30–40% of world CO_2 emissions from fossil fuels. Sulfur dioxide (SO_2) and NO_x contribute to acid rain [2].

Essential gaseous pollutants in the atmosphere are: carbon monoxide (CO), CO_2, methane (CH_4), nitric oxide (NO), nitrogen dioxide (NO_2), nitrous oxide (N_2O), sulfur dioxide (SO_2), chlorofluorocarbons (CFCs) and O_3. Global warming has been increasingly associated with the contribution of CO_2. Currently, it is estimated that CO_2 contributes about 50% to the anthropogenic greenhouse effect. In addition to CO_2, several other gases, e.g. CH_4, CFCs, halons, N_2O, SO_2, O_3 and peroxyacetylnitrate, produced by industrial and domestic activities, leading to the GHGs, can also contribute to this effect, resulting in a rise in the Earth's temperature [11–14].

5. Environmental issues

There is a growing concern that long-run sustainable development may be compromised unless measures are taken to achieve balance between economic, environmental and social outcomes. This section looks at three specific issues of sustainable development that are of particular importance for Turkey: addressing climate change, reducing air pollution and ensuing sustainable use of natural resources. In each case, indicators are presented to measure progress and the evolution of potential problems, and an assessment is made of government policies in that area. The section also considers whether institutional arrangements are in place to integrate policy-making across the different elements of sustainable development [7].

5.1. Climate change

Turkey's total CO_2 emissions amounted to 200 million tones (Mt) in 2004. Emissions grew by 5% compared to 2001 levels and by just over 50% compared to 1990 levels. Oil has historically been the most important source of emissions, followed by coal and gas. Oil represented 45% of total emissions in 2004, while coal represented 40% and gas 15%. The contribution of each fuel has however changed significantly owing to the increasingly important role of gas in the country's fuel mix starting from the mid-1980s [6–8].

According to recent projections, TPES will almost double between 2004 and 2020, with coal accounting for an increasingly important share, rising from 24% in 2004 to 36% in 2020, principally replacing oil, which is expected to drop from 40% to 27%. Such trends will lead to a significant rise in CO_2 emissions, which are projected to reach nearly 600 Mt in 2020, over three times 2004 levels [5].

In 2004, public electricity and heat production were the largest contributors of CO_2 emissions, accounting for 30% of the country's total. The industry sector was the second largest, representing 28% of total emissions, followed by transport, which represented 20% and direct fossil fuel use in the residential sector with 8%. Other sectors, including other energy industries, account for 14% of total emissions. Since 1990, emissions from public electricity and heat production have grown more rapidly than in other sectors, increasing by 6%. Simultaneously, the shares of emissions from the residential and transport sectors both dropped by 7% and 3% respectively while the share of emissions from the manufacturing industries and construction sector remained stable [6,7].

Per capita CO_2 emissions were at 3.0 tons in 2004, much lower than the OECD average of 11.0 tons. Between 1990 and 2004, per capita emissions in Turkey grew by 22% while on average they grew by only 4% at the OECD level and dropped by 3% in the IEA Europe region. Historically these emissions have been much lower than the OECD average. However, owing to the important growth in emissions that took place over the 1990s, by 2004 CO_2 emissions per unit of GDP were only marginally lower than the OECD average [7].

5.2. Climate change mitigation policies

Turkey was a member of the OECD when the UNFCCC was adopted in 1992, and was therefore included among the so-called Annex I and Annex II countries. Under the convention, Annex I countries have to take steps to reduce emissions and Annex II countries have to take steps to provide financial and technical assistance to developing countries. However, in comparison to other countries included in these annexes, Turkey was at a relatively early stage of industrialization and had a lower level of economic development as well as a lower means to assist developing countries. Turkey was not given a quantified emissions reduction or limitation objective in the Kyoto Protocol. Following a number of negotiations, in 2001 Turkey was finally removed from the list of Annex II countries but remained on the list of Annex I countries with an accompanying footnote specifying that Turkey should enjoy favorable conditions considering differentiated responsibilities. This led to an official acceptance of the UNFCCC by the Turkish Grand National Assembly in October 2003, followed by its enactment in May 2004. Turkey has not yet signed the Kyoto Protocol [3–8].

Throughout this process, the government carried out a number of studies on the implications of climate change and its mitigation. The first efforts were undertaken by the National Climate Coordination Group in preparation for the 1992 Rio Earth Summit. Following this, a National Climate Program was developed in the scope of the UNFCCC. In 1999, a specialized Commission on Climate Change was established by DPT in preparation of the Eighth Five-Year Development Plan (2001–2005). The Five-Year Development Plan was the first planning document to contain proposals for national policies and measures to reduce GHG emissions, and funding for climate-friendly technologies [10].

Following the ratification of the UNFCCC, a number of working groups were set up with the objective to define

a climate change mitigation strategy and compile the country's first national communication to the UNFCCC. These included a working group on mitigation in the energy sector and a working group on mitigation in the transport sector. However, it remains unclear as to when the strategy and national communication will be completed. The strategy aims to reduce GHG emissions through the implementation of appropriate measures and the development of climate-friendly technologies. Energy efficiency and the development of renewable energy sources are two important components of the strategy. However, the strategy will not include any policies that directly target GHG emissions, such as carbon taxation or emissions trading. It also does not include a specific target for emissions reductions [7,21].

5.3. Air pollution in Turkey

The main air pollutants related to the production and use of energy are CO, CO_2, CH_4, SO_2, NO_x and suspended particulates in Turkey (see Table 7 and Figs. 5–10). These emissions come mostly from the combustion of solid and liquid fuels. The use of high-sulfur lignite in particular is an important source of air pollution. As a consequence of efforts to move away from high-sulfur lignite to either imported coal or gas, air pollution concentration levels have reduced significantly in most large cities since the early 1990s [5,6,23,24].

On the other hand, concentration levels in smaller cities where gas distribution networks have not yet been built are higher than in larger cities. In addition to this, even in cities where average air quality has improved, air quality mapping reveals that high concentration hot spots exist around heavily used roads, particularly to the west of the country, owing to higher vehicle-ownership density [9].

In 2002, Turkey emitted a total of 2.10 Mt of SO_2, equivalent to 30.4 kg per capita. This is slightly below the OECD average, which at the end of the 1990s was 32.9 kg per capita. In terms of emissions per unit of GDP, Turkey

Table 7
Direct and indirect greenhouse gas emissions in Turkey between 1980 and 2010 (Gg)

GHGs	1980	1985	1990	1995	2000	2005	2010
Direct GHGs	110,216	133,056	200,720	241,717	333,320	427,739	567,000
CO_2	81,889	108,923	177,973	211,229	303,079	397,351	535,966
CH_4	27,574	23,265	21,618	24,302	25,585	25,531	25,640
N_2O	753	868	1128	6116	4656	4858	5394
NO_x	380	493	680	814	1154	1513	2073
CO	2936	3115	3715	3961	8390	9552	11,433
MNVOC	360	380	524	599	1415	1638	1991
SO_2	131	420	813	894	1038	1038	1038

GHGs: Greenhouse gases.
Source: Ref. [9].

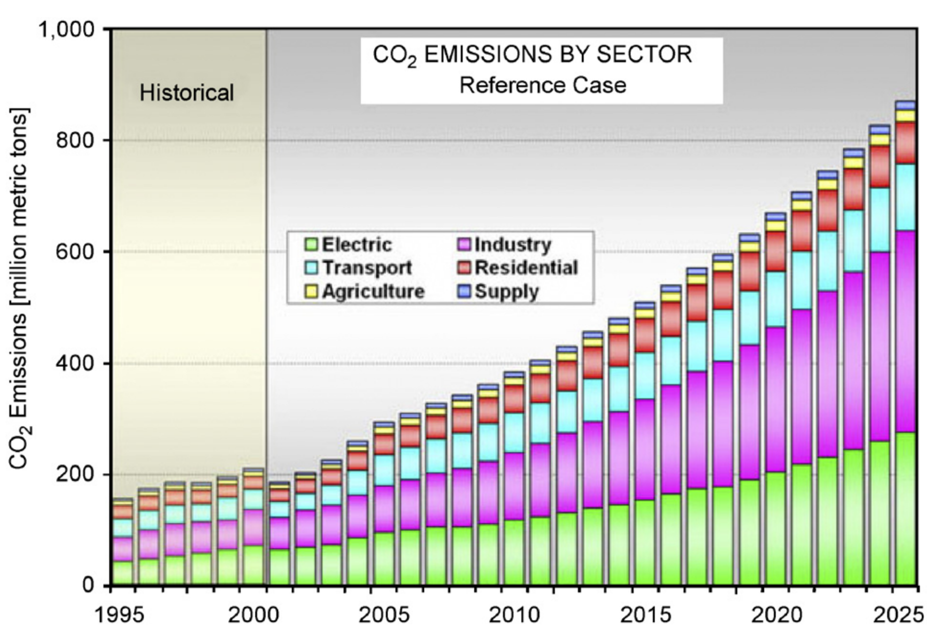

Fig. 5. Reference case CO_2 emission [23].

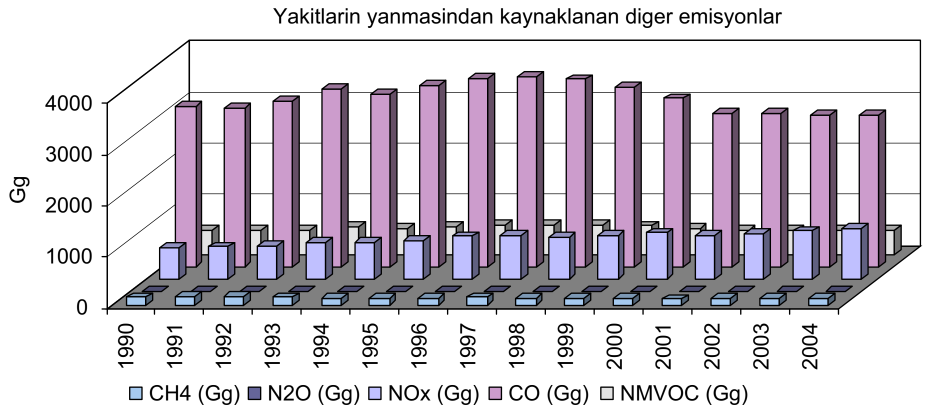

Fig. 6. Total CH_4, N_2O, NO_x, CO, NMVOC emissions from fuel combustion (NMVOC = non-methane volatile organic) [5,9].

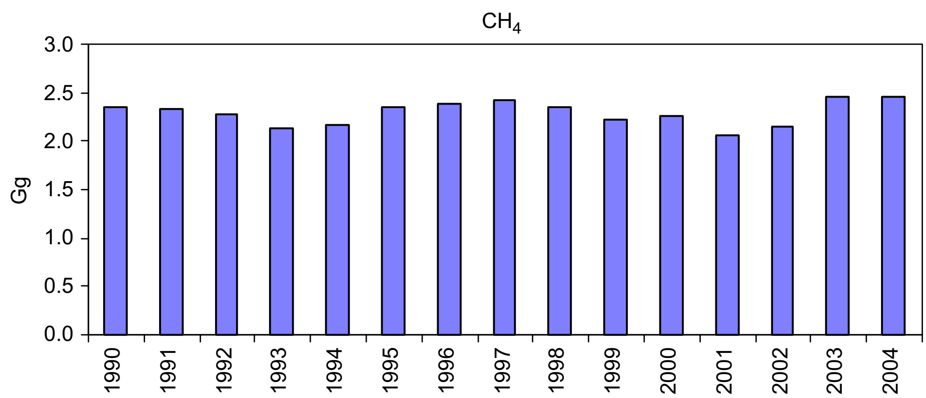

Fig. 7. CH_4 emissions from industrial processes [5,21].

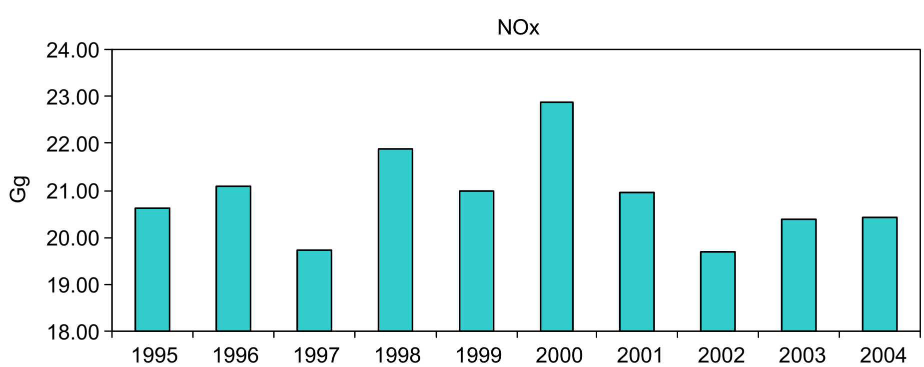

Fig. 8. NO_x emissions from industrial processes [5,21].

emitted 5.5 kg per US$1100 in 2002, among the highest levels in OECD countries where the average was approximately 1.5 kg per US$1000. Electricity generation and industry are by far the largest contributors to SO_2 emissions in the country, representing respectively 65% and 21% of total emissions in 2001 [6,7].

Total emissions of NO_x was about 0.90 Mt in 2003, slightly below 2000 levels of 0.92 Mt. NO_x emissions have nevertheless been rising over the past decades. According to the OECD, over the 1990s only, NO_x emissions grew by 48%. On a per capita level, emissions were of 13.0 kg in 2004, substantially below the OECD average of approximately 40 kg at the end of the 1990s. On the other hand, emissions per unit of GDP were at 2.1 kg per US$1000 in 2003, above the OECD average, which at the end of the 1990s was around 1.9 kg per US$1000. Transportation, and predominantly road-based transport, is the largest source of NO_x emissions, representing 36% of total

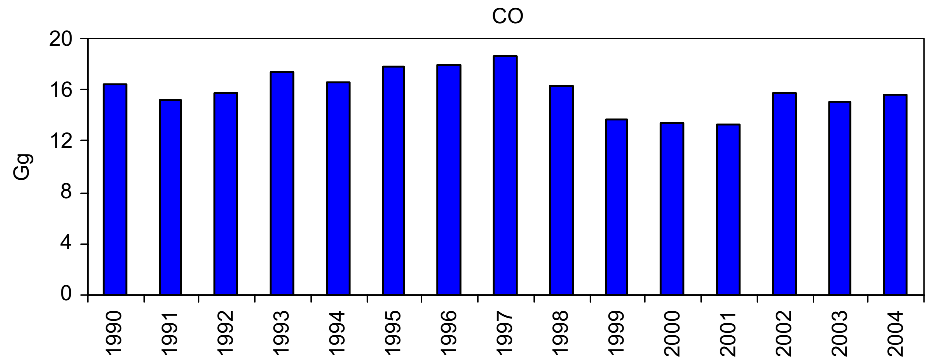

Fig. 9. CO emissions by industrial processes [21].

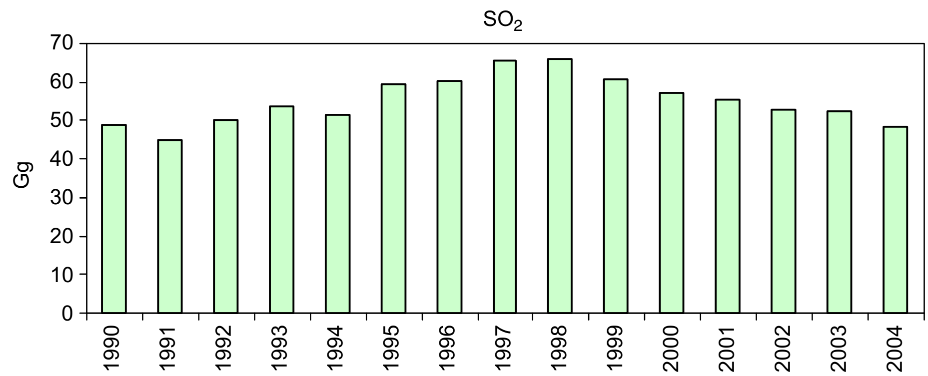

Fig. 10. SO_2 emissions from industrial processes [21].

emissions. Electricity generation and industry represent over 20% each.

Under a reference scenario prepared for the World Bank [5], particulate matter (PM) and SO_2 emissions are expected to grow at about 2.2% per year, reaching in the case of SO_2 over 3.8 Mt in 2025. NO_x emissions are projected to grow at 3.5% per year [6].

5.4. Abatement policies

Air quality standards for four pollutants, namely SO_2, NO_2, PM and O_3 are set under the 1986 Air Quality Protection regulation. The monitoring of ambient air pollution has improved over recent years but remains a problem, particularly with regards to NO_2 and O_3. On the other hand, until recently, the 1986 regulation was also responsible for setting air pollution standards for combustion plants. It was amended in October 2004 by the new Industrial Air Pollution Control Regulation [5–10].

The regulation sets standards for the emissions of NO_x, SO_2, CO and PM. NO_x and SO_2 standards have not changed compared to 1986 standards, while PM and CO standards have been lowered for both solid and liquid fuel-fired plants. In the case of PM, standards have been lowered from 150 to 100 mg/m^3 for solid fuel-fired power plants. For CO, standards have been lowered from 250 to 200 mg/m^3 in the case of solid fuel-fired plants and from 175 to 150 mg/m^3 in the case of liquid fuel-fired plants.

Given the high sulfur content of domestic lignite, new lignite-fired power plants have been equipped with flue gas desulfurization (FGD) technology in order to comply with the regulation. To reduce emissions from pre-1986 lignite-fired power plants, these plants are progressively being retrofitted with FGD technology. At present, six out of eleven lignite power plants have been retrofitted. No schedule has been defined for the five remaining plants. As regards particulate emissions, both new and old power plants have been fitted with electrostatic precipitators (ESP). However, owing to technical problems, not all ESPs are working at maximum efficiency [5–10].

The emissions standards for power plants remain significantly less stringent than those currently in force at the European Union (EU) level as defined by the revised Large Combustion Plants (LCP) Directive. For example, for new solid fuel-fired power plants with a thermal input greater than 300 MW, the NO_x emissions limit is set at 200 mg/N m^3 at the EU level, while the NO_x emissions limit is 800 mg/N m^3 in Turkey. On the other hand, first estimates show that achieving the standards defined under the LCP directive would entail investments of over US\$1 billion. This would include investments in the retrofitting of installed FGD and ESP equipment and the adoption of advanced and environment-friendly coal

technologies. The 2004 Industrial Air Pollution Control Regulation is an important step towards aligning air quality standards with EU regulations, but more efforts will be needed [21,23,25].

Construction of one power plant based on circulating fluidized bed technology has recently been completed. The plant is the first application of advanced coal technology in Turkey and has been designed to use low-quality lignite with high sulfur content. The industry and residential sectors are also responsible for significant air pollution, mainly as a result of lignite consumption. In order to reduce emissions from these sectors, the state-owned Turkish Coal Enterprises (TKI) has developed significant lignite washing capacity. By the end of 2004, total washing capacity was approximately 10.4 Mt, equivalent to current coal demand from both sectors. In addition, the use of high-sulfur coal in residential heating is prohibited. Lastly, the substitution of gas as distribution networks are expanded in urban areas should further contribute to reduce air pollution [5–8,21,25].

6. Sustainable development

There is a growing concern that long-run sustainable development may be compromised unless measures are taken to achieve balance between economic, environmental and social outcomes. This section looks at three specific issues of sustainable development that are of particular importance for Turkey: addressing climate change, reducing air pollution and ensuing sustainable use of natural resources. In each case, indicators are presented to measure progress and the evolution of potential problems, and an assessment is made of government policies in that area. The section also considers whether institutional arrangements are in place to integrate policy-making across the different elements of sustainable development [7,23].

The integration of policy in Turkey is pursued through the inclusion of sustainable development objectives in overarching policy initiatives. Sustainable development is one of the main aims of the Eighth Five-Year Development Plan, which covers the period 2001 to 2005. It incorporates policies adopted in the 1998 National Environment Action Plan, which identified investment programs for enhancing environmental management based estimated costs and benefits. The plan was based on a widespread consultation among stakeholders. Despite the attention paid to sustainable development in policy making, there are problems in implementing policies. For example, the Ministry of the Environment has lacked sufficient authority to enforce environmental legislation and the majority of public officials are unaware of requirements in environmental protection legislation. A recent reform to the Ministry of the Environment has strengthened its administrative capacity and expanded the coverage at the sub national level [5].

The use of cost–benefit analysis is not systematically applied to policies and projects in Turkey. The use of environmental impact assessments was introduced in 1993 for major infrastructure projects, but in 1997 requirements were weakened considerably in order to complete projects started before the legislation was introduced. This downscaling of requirements was undertaken in response to concerns about environmental impact assessment (EIA)-related costs and time delays voiced by domestic and foreign investors. However, in 2002, positive EIA in sustainable development policy making was again strengthened [5].

Economy-wide GHG emissions from fuel combustion jumped 65% in the 1990s, in contrast to the more modest growth in the rest of the OECD area. Although Turkey has been growing more rapidly than the rest of the OECD area, the principal reason for the relatively rapid growth in emissions has been the very different evolution in the GHG intensity of the economy generated both by an increase in the use of energy per unit of output and an increase in GHG emissions per unit of energy supplied from renewable sources such as wood, animal waste, hydroelectricity and geo-thermal energy. However, despite the more rapid growth of economy-wide GHG intensity, by 2000 CO_2 emissions per unit of GDP were similar to the average in the OECD area [7,19,22].

The Turkish government is now in the process of developing a strategy to reduce the growth of GHGs. This strategy will be elaborated in the context of Turkey's adhesion to the United Nations Framework Convention on Climate Change (UNFCCC). Turkey passed the national legislation to ratify the convention in January 2004 and adhesion will take effect in May. Following adhesion, Turkey will have the obligation to implement measures and polices to mitigate GHG emissions but will not be required to meet a specific GHG emission target. Turkey will submit its first national communication to the UNFCCC by the end of 2004, including the measures that it proposes to take to limit emissions. This document will draw on existing policies as outlined in the Eighth Five Year Development Plan that contained a number of proposals to limit the growth of emissions [5–8].

Turkey shares a number of features with some other OECD countries that suggests it would be possible to considerably moderate the growth of GHGs with little or even no cost. The proportion of energy derived from carbon-intensive coal and lignite is one of the highest in the OECD area, reflecting ample reserves of lignite, while a completely liberalized market in natural gas has not existed. Most GHG emissions in Turkey come from electricity generation sector that has been a largely state-owned industry operating under non-commercial criteria. Subsidies have been growing following a government decision to expand the industry in the late 1990s after a period of cutbacks in employment and output. The import of natural gas has been controlled by another state-owned enterprise that makes all contracts for the import of gas. Currently, consumer prices are held low because the government has to pay for certain imported gas whether

it is used or not and also in order to encourage households to convert to gas [17].

The privatization of the electricity companies will also result in new pricing policies. At present, demand for electricity is boosted by a high level of what is called ''non-technical'' system losses. In practice, this phrase refers both to electricity that is consumed through illegal connections to the network and non-payment of bills. Overall, a significant proportion of electricity (around 23%) is provided without charge. The new distribution companies will need to invest in new metering systems to ensure that these practices end. The problem may be difficult to settle, in that the new distribution companies have different profiles of losses, with illegal consumption rising to 50% in some areas. Enforcing normal contract discipline, though, would further add to the de-coupling of carbon emissions form GDP growth. In addition, both the overall price of electricity may have to rise to reduce the losses of the electricity industry and domestic and industrial tariffs will have to be re-balanced. It is not clear, though, what the overall balance of this re-balancing will be on overall electricity demand. At present, the government is considering what measures in the social area are necessary to complement electricity price liberalization. It would seem appropriate to separate pricing from social support. The electricity price can then be used to achieve an efficient distribution of resources and the social instruments can then be used to achieve equity goals [8–10].

While fossil fuels are likely to become less carbon intensive, the supply of renewable energy is unlikely to keep pace with the growth in the economy. First, consumers are likely to switch away from animal waste as a fuel source as incomes grow, while wood resources are limited by deforestation concerns. In addition, even with a planned tripling of hydro capacity in the period from 2000 to 2020, the share of hydro in total electricity generation will fall [4]. In addition, the environmental consequences of such an expansion will have to be carefully monitored as will overall costs as most of the expansion in the period to 2010 is expected to come from small-scale hydro projects, which are often linked to irrigation projects. However, the DSI (the government agency responsible for managing the country's water resources) has estimated that large South-East Anatolia Project (GAP), a combination of hydro-electricity plants and irrigation systems, has benefits that outweigh costs by a factor of over three to one [26].

There is an ongoing policy initiative to promote energy efficiency. This represents a continuation of energy conservation policies that have been in place since the early 1980s. A framework law on energy efficiency is being elaborated. Currently, policies promoting energy efficiency include audits of large industrial enterprises and training for managers, tightening energy-efficiency standards for appliances, and requiring greater energy efficiency in buildings and motor vehicles (Ministry of the Environment/UNDP, 2002). Little is known about the cost efficiency of these measures. More extreme government energy-saving measures, such as the switching-off of street lighting, are likely to impose a significant cost on the economy [5].

7. Renewable energy for climate change mitigation

7.1. Renewable energy for solution to climate change

Climate change is arguably one of the greatest environmental threats the world is facing. The impacts of disruptive change leading to catastrophic events such as storms, droughts, sea level rise and floods are already being felt across the world. On the other hand, while the Kyoto Protocol, which aims to reduce GHG emissions is slowly impacting on energy markets, scientists are increasingly advising policymakers that carbon emission reductions of beyond 60% are needed over the next 40–50 years [26–28].

At the heart of the issue is an energy system based on fossil fuels that is mainly responsible for GHG emissions. On the contrary, renewable energy provides one of the leading solutions to the climate change issue. By providing 'carbon-neutral' sources of power, heat, cooling and transport fuels, renewable energy options such as wind, solar, biomass, hydro, wave and tidal offer a safe transition to a low carbon economy [18,19,27].

The concept of a transition to a carbon-free economy has become broadly understood and been outlined by many actors from G81, the United Nations, the International Energy Agency, Governments and industry alike. In the long run, renewables are the only energy sources that provide a sustainable carbon neutral energy supply. This briefing outlines the role that renewable energy can play in reducing GHG emissions such as carbon and CH_4. It highlights the success to date and the activity already happening across Europe and the rest of the world. It assesses its potential, and identifies how renewable energy is central to climate change policy and delivering large CO_2 reductions [26].

According to the vast majority of climate scientists, climate change is already underway. The past decade has seen the warmest 6 years since records began. A third of global habitats are at risk, and extreme events such as floods, storms and drought are becoming more frequent. The financial consequences of climate change are also becoming apparent-with insurance claims due to weather-related damage increasing dramatically over the past few decades.

The Inter-governmental Panel on Climate Change (IPCC) stated in its Third Assessment Report in 2002 that: ''there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities.'' It predicts that global average temperatures are likely to rise between 1.4 and 5.8 °C over this century, depending on the amount of fossil fuels we burn and the sensitivity of the climate system. On the other

hand, the IPCC identifies the following effects of an increase in global average temperature [28]:

- Steady rise of the sea level
- Flooding of coastal areas
- Frequent extreme weather conditions
- Frequent poor harvest
- Water shortage
- Devastations
- Loss of biodiversity
- Increase of infections.

A precautionary approach to this threat requires global temperature increase to be limited to less than 2 °C above pre-industrial levels in order to prevent further damage. It is very likely that a more than 1 °C temperature increase in the climate system is already irreversible, so keeping to the 2 °C limit will need urgent action over the next two decades. The rapid rise in the frequency and costs of natural disasters is beginning to make the costs of inaction transparent and many insurance companies are joining the call for reductions in fossil fuel use.

To achieve that will require keeping global CO_2 emission concentrations below 450 parts per million (ppm), a challenging task given that emissions are still increasing and that emission reductions in a number of industrializing countries are unlikely in the short term. That puts a major emphasis upon regions like the European Union to make deeper cuts in emissions. On the other hand, the climate change problem is essentially a fossil fuel energy problem. While agriculture, land-use changes, cement production and the use of chemicals all contribute to GHG emissions, more than 70% of the problem is due to the unsustainable use of fossil fuels. The climate change challenge means shifting away from fossil fuels in the home, industry, at work and the way we travel. Furthermore, global energy demand is predicted to rise as countries industrialize and population continues to grow. Renewable energy offers safe, reliable and increasingly cost-effective alternatives for all our energy needs such as heating, cooling, electricity and motive power for transport [26,27].

The natural flows of energy on planet earth provide a huge potential for harnessing carbon-neutral energy for society. Powered by the sun, the flows of wind power, hydropower, biomass, wave, tidal and solar heat and power—which can be captured by modern technology—are more than enough to provide for all our needs. The sun powers planet earth and allows us to survive. With smart technology it can also provide heat and electricity. It is also the driver for wind power. Wind in turn creates waves, a huge potential power source being tested worldwide in prototype schemes. The sun also powers the evapotranspiration cycle, which allows water to generate power in hydro schemes—currently the biggest source of renewable electricity in use today. Plants photosynthesize in sunlight and create a wide range of so-called biomass crops ranging from wood fuel to rapeseed, which can be used for heat, liquid fuels and electricity. Interactions with the moon produce tidal flows which can be intercepted and produce electricity. Though humans have been tapping into renewable energy such as wood, solar and water power for thousands of years, so far we have managed to capture only a fraction of the technical and economic potential of renewable energy sources [27].

The recent development of smarter and more efficient technology has been impressive. In the past 20 years these technologies have improved and costs have fallen dramatically. For solar photovoltaic (PV) cells, stimulated initially by the space program, unit costs have fallen by a factor of 10 in the past 15 years. Onshore wind power at good sites can compete with traditional fuels, and modern biomass heating is invariably cheaper than oil heating.

7.2. *Renewables in Turkey*

The government considers alternative transport fuels to be an important option in the longer term to mitigate energy security concerns and reduce GHG emissions. However, it deems current technologies to be expensive and a risky investment, while not offering significant life cycle GHG reduction benefits, especially if the fuel is derived from fossil fuels. On the other hand, the government is in the process of drafting an energy-efficiency law, which will include provisions for the use and promotion of biofuels; the draft renewable energy law does not cover biofuels. The government is considering the introduction of tax benefits to promote biofuels. Another promotional provision will be a 1% biofuel supply obligation, which will be introduced for the oil distribution licence holders. Biofuels as well as fuel cells and hydrogen technologies are among the priority areas of government-funded energy research and development [3,4,7].

Turkey has substantial renewable energy resources. Renewables make the second-largest contribution to domestic energy production after coal. In 2003, energy from renewable sources amounted to 10 Mtoe (12% of TPES). This shows very little increase from 1990 when 9.7 Mtoe renewables were used (18% of the TPES). More than half of renewables used in Turkey are composed of combustible renewables and waste, the rest being mainly hydro and geothermal (see Tables 4 and 5). Combustible renewables and waste used in Turkey are almost exclusively non-commercial fuels, typically wood and animal products, used in the residential sector for heating. The use of biomass for residential heating, however, has declined owing to replacement of non-commercial fuels by commercial fuels. The contribution of wind and solar is still small but is expected to increase. Electricity generation from renewables totalled 35.5 TW h and contributed 25% to total generation in 2003. In 1990, generation from renewables was 23.2 TW h and their share in power generation was higher, representing 40%. Hydro is the dominant source of renewable electricity, with only

0.15 TW h derived from other sources. Hydro production fluctuates annually depending on the weather [5–8].

7.2.1. Hydropower

Hydropower generation climbed from 2 Mtoe (23.1 TW h) in 1990 to 3.0 Mtoe (35.3 TW h) in 2003, growing on average by 3.8% per year. The economic hydropower potential has been estimated at 128 TW h per year, of which 35% has been exploited. The government has a strategy for developing the hydropower potential and expects a few hundred plants to be constructed over the long term adding more than 19 GW of capacity. Construction costs would be approximately US$30 billion. The government expects hydropower capacity to reach about 31,000 MW in 2020. Some 500 projects (with a total installed capacity over 20,400 MW), which are in different phases of the project cycle, are awaiting realization. On the other hand, Turkey has a lot of potential for small hydropower (<10 MW), particularly in the eastern part of the country. At present the total installed capacity of small hydropower is 176 MW in 70 locations, with annual generation of 260 GW h. Ten units are under construction with a total installed capacity of 53 MW and estimated annual production of 133 GW h. Furthermore, 210 projects are under planning with a total capacity of 844 MW and annual production of about 3.6 TW h [29–32].

7.2.2. Geothermal energy

The contribution of geothermal to TPES was 0.86 Mtoe in 2003, including 89 GW h of electricity generation. Turkey has significant potential for geothermal energy production, enjoying one-eighth of the world's total geothermal potential. This potential has been estimated at 4.5 GW of electric capacity (GWe) and 31.1 GW of thermal capacity (GW_{th}); most of this is of relatively low enthalpy making it unsuitable for electricity generation but can still be used for direct heating applications. By the end of 2003, Turkey's total direct geothermal heating capacity was 1077 MW_{th}, of which 619 MW_{th} provided heat for 71,000 residences, 131 MW_{th} for 63.5 ha of greenhouses and 327 MW_{th} was used to provide hot water to about 200 spas. The government estimates that 500,000 residences could be heated by geothermal power by 2010, representing heat use of 2190 MW_{th} [33–37].

Despite having already announced the first geothermal energy program in 1972, Turkey still has only one operating geothermal power plant, a 17.5 MW_e facility in the Denizli-Kızıldere field. The facility includes nine production wells and has an integrated liquefied CO_2 and dry ice production factory. Another geothermal power station (49 MW_e) and five heat plants (73 MW_{th}) will be added. Two geothermal electricity generation projects with a capacity of 13.45 MW and a slightly smaller one have been licensed. The cost of electricity from geothermal resources is between €0.03 and €0.10 per kWh; the bottom end of this range is competitive with conventional systems. There are 11 other geothermal fields, all in far south-west Turkey, which may be suitable for geothermal power production. The Germencik-Aydın field in the Aydın Province is the most promising one. Power generation potential in this field has been estimated to exceed 100 MW_e [34–37].

7.2.3. Solar energy

According to a solar estimate made in 1983, there are on average 2640 sunshine hours per year in Turkey and the average solar intensity is 3.6 kWh/m^2 day. However, because these historical estimates are not sufficiently accurate for electricity generation projects, new solar potential measurement projects are under way and data will be collected in selected sites in different parts of the country over a 5-year period. At the moment, measures are being conducted in the cities of Ankara, Adana, Isparta, Kayseri and Balıkesir. The measurements in the cities of Antalya, Izmir and Aydın cities have been completed [3,4,6,38].

Flat-plate solar collectors used for domestic water heating are widely used and commercially available in Turkey. In 2003, the collector surface area installed in Turkey was 10 million m^2, including both household systems and large-scale use in hotels, industrial activities, etc. Using these collectors for heating contributed 0.35 Mtoe to energy production. Annual collector manufacturing capacity is 1,000,000 m^2. The EIE installed a computer-aided test stand in order to enable the manufacturers to improve the quality and efficiency of the collectors. It used the test stand to help the Turkish Standard Institute to develop new standards for collectors. On the other hand, the EIE has also developed a parabolic solar cooker and has studied the possibility to use vacuum tube solar collectors in heating and cooling. In the area of PVs, the EIE has implemented some small-scale stand-alone systems but also one grid-connected project. Examples of the stand-alone PV systems are a few lighting units, traffic warning systems used during road maintenance works, irrigation and pumping systems. In order to investigate the operational properties of PV systems, one stand-alone 1.6 kW peak (kWp) PV system for power generation was installed already in 1985. A 4.8 kWp grid-connected PV system is installed in Didim Training and Research Centre to gain experience about the operating problems of grid-connected systems. Another 1.2 kWp grid-connected PV system was installed in Ankara in 2002 [4,8,21,38].

7.2.4. Wind energy

According to Turkey Wind Atlas, Turkey's technical wind energy technical potential is 88,000 MW and its economic potential is 10,000 MW. The Aegean coast, Marmara and the East Mediterranean regions are very favorable locations for wind power generation. In recent years, interest in wind energy has greatly increased in Turkey with many studies on the resources and private sector investing in wind power plants. At present, total

installed wind power capacity is 85 MW in two power plants in Izmir, one in Canakkale and one in Istanbul. Furthermore, licence applications for a total capacity of 4800 MW have been submitted to Energy Market Regulatory Authority (EMRA) by private developers after the beginning of the electricity market reform. Wind measuring stations have been installed in many parts of the country to enable the evaluation of the wind potential. This has not been done solely by the public sector as wind measurements have been carried out at nearly 500 different sites by private enterprises as part of feasibility studies for wind power plants [39–41].

Wind measurement data from the past 10 years (1989–1998) were processed in 2002 into a Wind Atlas, which gives a general idea about Turkey's wind potential. This study was carried out by the EIE and the State Meteorological Organization. In the study, data for 45 selected meteorological stations were processed. Long-term planning studies projects that wind energy capacity could reach 1769 MW by 2010 and 3019 MW by 2020. On the other hand, wind Atlas will be further converted into a Wind Energy Potential Atlas by considering the current wind data, land structure and grid connection. The objective is to define areas where wind energy can be used and to provide necessary information to planners and investors [5–8,38–41].

7.2.5. Biomass

Biomass energy has a number of unique attributes that make it particularly suitable to climate change mitigation and community development applications. Biomass fuel sources are readily available in Turkey as other developing countries, particularly in rural areas and do not have to be imported. Biomass-based industries can be a significant source of jobs in rural areas, and sustainable land management activities can promote biomass regrowth, allowing more CO_2 to be absorbed. Among the renewable energy sources, biomass is important for Turkey because its share of total energy consumption is still high. Since 1980, the contribution of the biomass resources in the total energy consumption dropped from 20% to 10% in 1998. Biomass in the forms of fuelwood and animal wastes is the main fuel for heating and cooking in many urban areas. The total recoverable bioenergy potential is estimated to be about 16.92 Mtoe. The estimate is based on the recoverable energy potential from the main agricultural residues, livestock farming wastes, forestry and wood processing residues, and municipal wastes that given in the literature [42–45].

On the other hand, fuelwood is important for rural area in Turkey as in other developing countries. About half of the world's population depends on fuelwood or other biomass for cooking and other domestic use. In 2000, an estimated 18 million m^3 of fuelwood were produced by the State, while from both public and private sectors recorded production was estimated at about 18 million m^3 from undeclared production. In other words, approximately half of the total demand for fuelwood is met by informal cutting in State forests and other sources of fuelwood in agricultural areas [45].

Although energy forests are considered a renewable energy source, they can disappear in time due to continued usage. Short-rotation energy forestry involves growing species of willow planted close together as capping. The crop is planted as cuttings using clonal material at around 1–2 m spacing. Management of the crop is intensive, with complete weed control absolutely essential if the crop to be economically viable. The crop is harvested on cutting cycles of 4–6 years, depending on species and site. This is very important for the country's economic and social conditions. Because the forest cannot supply enough for heating and cooking purposes, plantations of energy forests should be planned and implemented very carefully in the country. The harvest intervals of the energy forests should be longer than 4–6 years [44,45].

Biogas production potential has been estimated at 1.5 to 2 Mtoe but only two small units (in total 5 MW) are in operation and one new facility (1 MW) has been licensed. There are, however, R&D activities in the area. At the end of 2003, the total installed capacity of waste-fired power plants was 27.6 MW, all of which was in the industrial sector. One waste-fired power plant with 11.5 MW of installed capacity was commissioned in 2004. There are no power plants in operation using biomass [5–7].

8. Conclusions

The implementation of market-based reforms in the electricity sector offers the possibility of significant improvements in economic efficiency and a reduction in the rate of growth of GHG emissions. Such reforms have been mooted for many years and have run into considerable barriers, not the least of which is the need for a realistic pricing strategy. A further crucial prerequisite for achieving a successful involvement of the private sector will be the phased introduction of a cost-based tariff structure. Equally, the recent expansion of the hard coal industry needs to be rolled-back and restrictions on the import of natural gas lifted through the transfer of gas import rights to potential new competitors and the restructuring and privatization of the national gas company. State intervention is likely to continue in the area of hydro-power where an expansion of capacity will need to balance the benefits from a low-cost low-emission source of energy against possible environmental and social costs. Overall, the current thrust of market policies point towards a slowing in the growth of CO_2 emissions. The new renewable energy policy may also help hold back emission growth as it is designed in way that limits costs.

Investment in air pollution control has been found to be socially profitable in most countries and Turkey is not an exception. The cost of achieving EU pollution emission

limits may appear high, but benefits will in most cases outweigh costs, which in any case will be relatively limited in comparison to the average price of electricity. An increase in the capabilities for monitoring and enforcing existing and future legislation will be required, if the reduction emission limits is to be effective. At the same time, more recognition needs to be given to the benefits from pollution reduction. In any case, the current infrastructure makes it unlikely that trading or taxation systems could be effectively introduced. However, in the residential and transport markets, there is more scope for the use of taxation as an instrument to improve air quality by placing higher taxation on more polluting fuels.

A new renewable energy policy is being developed by the government. The principal focus will be the development of renewable sources of electricity production. The regulations governing the new transmission company require it to give absolute priority to renewable energy in the priority system for the connection of the generation facilities to the grid. In addition, retail licensees are obliged to purchase all renewable energy output but only when the price offered by the renewable energy supplier is at or below the public wholesale price of electricity and when an alternative supply of renewable electricity is not available at a lower price.

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